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Matthew Effects in Education

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To test the hypothesized cumulative advantages of educative factors, the science-achievement scores on a 69-item test of science knowledge of 1,284 young adults, ages 26 to 35, surveyed by the National Assessment of Educational Progress (NAEP) in 1977, were regressed on three composite independent variables: motivation and prior and current educative experiences. The test scores were related significantly to prior experience-embodied variables, such as parental socioeconomic status, respondent education, and specific scientific training, as well as to motivation to learn and current amount and intensity of information acquisition, such as news media exposure and reading. Early educative experience predicts current educative activities and motivation; and all three factors contribute significantly and independently to the prediction of achievement.

For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath.
(Gospel according to Matthew, XXV, 29)

It is often said that education is a good economic investment; and, indeed, Theodore W. Schultz, in Nobel prize winning research, showed that education generally pays excellent monetary returns to individuals and nations, even considering inflation and foregone opportunities to work during the school and college years. Investments in people, or "human capital," are also associated with health, longevity, civic participation, self-rated happiness, and other adult outcomes (see Schultz, 1981, for a survey of evidence from many periods and countries). Such benefits have been demonstrated repeatedly; but the variables that intervene between educational experiences and adult outcomes, such as knowledge acquisition and the capacity to invest, persevere, and profit intellectually from experience, are seldom investigated, even though they may be considered valuable intermediate products, by-products, or consummatory ends in their own right. The present research explores these intervening variables. Specifically, it investigates a hypothesized enhancement of knowledge acquisition from (a) current educative activity, (b) motivation, and (c) prior formal education and informal educative experience.

The enhancement, cumulative-advantage or Matthew hypothesis, is discussed in the subsequent sections. The introductory discussion is somewhat extended and discursive for several reasons. Research in education is often atheoretical or guided by implicit theory and should be made theoretically explicit if it is to be made falsifiable in Popper's (1972) sense (see also Cook & Campbell, 1979, pp. 20–25). Moreover, several versions of the Matthew hypothesis and related concepts require explication and empirical probing. Lastly, prior evidence on the Matthew and related effects originates in mathematical topics and disciplines outside the mainstream of educational research, notably the microeconomics of investment and productivity; this scattered evidence deserves a brief review.

MATTHEW AND FAN-SPREAD EFFECTS

A close reading of the gospel passage quoted above and its context suggests that the Matthew effect as originally set forth was absolute and volitional: absolute in that those who hid and thereby merely preserved their wealth, whatever its initial size, rather than investing and multiplying it, would lose it all rather than keeping it or gaining relatively less at a lower rate; and volitional or motivational in that individuals make decisions determining their fate. The modern "fan-spread" hypothesis, however, holds that rates of gain are relative and proportional to initial endowment.

A comprehensive review of experimental and quasi-experimental effects describes a "fan-spread" of beneficial growth during educational or other experience such that those who score higher than others on pretests or other desirable attributes relevant to a treatment at the beginning of an experiment gain absolutely and relatively more than others from the same experience (Cook & Campbell, 1979, pp. 184–185). The increasing variation during the course of experience leads to a fan-spread of points when outcomes are plotted against time.

The Equality of Educational Opportunity National Survey, for example, revealed that socioeconomic and ethnic groups that scored somewhat higher than others in the early grades scored much higher in the later grades; and the gap or cumulative advantage increased steadily with grade level (Coleman et al., 1966). In a secondary analysis of the extensive Sesame Street evaluation data, moreover, Cook, Appleton, Conner, and Schaffer (1975) found general average test benefits to the children who watched the television program but also, contrary to the program goals, an increasing gap over time between poor and middle-class children as a consequence of viewing. The cumulative advantage appeared attributable to more extensive and reflective discussions of the program encouraged by middle-class parents.

Even before school, children differ greatly in the amount and intensity of parental care invested in them. By imputing foregone wage rates of mothers and obtaining information on hours of care spent with their children and the number of children per family in about 1,000 households, Hill and Stafford (1974) estimated that the maternal care embodied in preschool children of higher and lower socioeconomic status was worth respectively \$8,528 and \$1,702 in 1965, a ratio of about five to one. Thus it might be expected that such large variation may account for children's widely varying capacities to profit from schooling and other subsequent educative experience.

ECONOMIC PRODUCTIVITY

Starting in the 19th century, economists noted that not only do the rich get richer, but such acquisition may be attributable to multiple factors rather than simply virtue, wealth, or motivated effort alone. Cobb and Douglas first empirically demonstrated such simultaneous multiple causes in 1928. The 19th-century farm affords an instructive example of their classical economic productivity theory. Given quantities or intensities of the multiplicative factors of land, capital equipment, and labor, raising any factor will increase output. Raising a factor that has a high ratio to the others, however, will be less productive than otherwise; adding additional labor, for example, to an intensively cultivated farm makes for less allocative efficiency than adding more land or better seed.

The Cobb-Douglas (1928) production function has an excellent record for parsimoniously fitting productivity data for many periods and countries (see, e.g., Bosworth, 1976; Jones, 1976). It postulates that estimated output is an explicit multiplicative function of the factors labor and capital, $O = aL^bK^c$, in which the lower-case letters are fitted constants, that is, linear multiple regression weights for the logged variables. The Cobb-Douglas function usually subsumes land under capital in economics, but, to reflect more closely the specific technology, the factors may be disaggregated, for example, into equipment, land, seed, fertilizer, irrigation, management, tilling, and rotation, and the coefficients may be simultaneously estimated separately in a single multiple regression. Sets of exponents that sum to one, which are often observed, imply constant "return to scale" of the technology; for example, doubling the quantities of both labor and capital simultaneously doubles output. Sums greater or less than one imply respectively increasing or decreasing returns to scale.

EDUCATIONAL PRODUCTIVITY

Casting school learning and its major correlates—motivation, ability, and instruction—into a Cobb-Douglas formulation suggests several hypotheses (Walberg, 1981). If any factor is at a zero point (setting aside the difficult problem of measurement), no learning can occur because zero multiplied by zero yields zero; thus, for example, zero motivation, time, or ability can each vitiate learning. With the other factors fixed, moreover, adding more of a factor will lead to diminishing returns to the factor if its exponent is less than one, as has been shown in the case of instructional time (see Frederick & Walberg's, 1980, review). In addition, when learning is regressed on the factors, each can be hypothesized to carry significant weight and make a unique contribution to the equation. Because motivation is included as an independent variable in Matthew, in the Walberg theory, and many formulations (see, e.g., Willson's, 1981, meta-analysis) it plays a similar role in the present theoretical formulation.

Larger investments in educative conditions in the family, in years of general education, and in specific learning may provide constructive experience for later learning. Such experience might be expected to make current learning more efficient; that is, more might be learned in a given amount or unit of activity. Thus the three factors treated in the present Cobb-Douglas formulation are motivation, prior educational experience, and current educative activity.

It is also possible, however, for cumulative advantages to occur without multiplicative efficiencies and interactions in that early environments may predict later environments that add further knowledge; an additive linear model is sufficient in this case without log transformation. In either case, learning specific bodies of knowledge during the life span may be analogous to the Matthew effect in science (Merton, 1968), in which initial advantages of university study, work with active eminent scientists, early publication and job placement confer tastes, skills, rewards, and further opportunities that cumulate to enable as few as the top fifth of natural scientists in various fields to produce or acquire four-fifths of the publications, citations, and awards (Merton, 1968).

PSYCHOLOGICAL PRODUCTIVITY

In both science and learning, the quantity, association, and abstraction of underlying cognitive elements seem essential for increasing knowledge. Simon (1979) and other cognitive psychologists showed that a greater number and richness of associations of permanent memory units acquired through specific prior experience allows new units to be acquired more rapidly by association with prior units and other learning-to-learn processes. Also developed in prior experience with specific bodies of knowledge is "chunking," or abstracting sets of discrete units and treating them as wholes, which allows more efficient acquisition and processing of new knowledge. As Simon (1979) acknowledges, however, prior and current acquisition involve more than exposure and cognitive processes since both causally involve motivation (see also Willson, 1981).

Research on labor economics and mass communication effects shows similar cumulative cognitive advantage and knowledge gaps. Nelson (1981) concludes, for example, that better and more recently educated farmers and doctors are able to better assess new technological developments in their fields and adopt promising ones early; and that, in general, workers of higher educational attainments migrate to new, rapidly growing industries that require rapid learning by doing. Roberts and Bachen (1982), moreover, conclude from a review of communications research that groups of higher socioeconomic status (SES) acquire information from the mass media faster than do lower SES groups and thus increase their cumulative advantage in knowledge. These reviewers suggest the possibility that efficiency in current acquisition of knowedge from media may be attributable to motivation to acquire it rather than earlier cognitive embodiments. Willson (1981) also points to the possible causal role of motivation in science achievement. Because of several alternative variables explanations, it seems most constructive to investigate these rival, or possibly joint or interactive, causes simultaneously controlled for one another in multivariate analysis, and to hypothesize, as in the present research, that knowledge acquisition is determined by motivation as well as amount and intensity of past and current educative activities.

METHOD

In this section, the sampling and instruments are described. The compositing of the variables and the translation of specific hypotheses into statistical tests, however, are presented in the section on results.

Sample

The National Assessment of Educational Progress (NAEP) provided data for this research. NAEP employed a stratified, multistage, area-probability sample design to ascertain the performance of young adults in 1977. The target population consisted of those born between January 1941 and December 1950, who were from 26 to 35 years old at the time of the assessment. Ninety-six interviewers attempted to administer packages to all eligible people in sample households. In the first stage of sampling, the United States was divided into 58 primary sampling units (PSUs), comprised of Standard Metropolitan-Statistical Areas (SMSAs) and counties or groups of contiguous counties with a population of at least 20,000. The PSUs were then stratified by region of the country and SMSA/non-SMSA status.

The next stage of sampling involved the selection of 2,265 housing units (SHUs), of which 2,213 were eligible and occupied. In these housing units were 1,379 age-eligible, English-literate, and physically and mentally undisabled adults who were willing to participate in the survey.

Instrument

The interviewers asked each respondent to complete a background questionnaire and test booklets, for which an incentive payment of $5 was offered. The test booklet for this research consists of 54 five-choice, objective achievement test items on science with an internal consistency of .79 for the sample employed in the analysis. The test covers three areas: science content, including biology, physical science, and integrated topics; science processes, including inquiry and decisionmaking; and science and society, including social problems, science and the self, and applied science.

The science booklet also contains 65 science motivation items concerning the respondent's opinions about the extent to which scientists should be given financial support for studying such things as nutrition and continental drift and about the degree to which science can help solve problems such as energy, weather, nutrition, disease, and birth defects. The internal consistency of the total of the binary-scored items is .68 for the sample.

Procedure

Analyses of variance were computed to investigate the association of the science-test scores with motivation and single items concerning past and current educative experience. As explained in a subsequent section, the item responses were used to form weighted composites. The test scores were regressed on linear and logged forms of the variables as well as their products and quadratic forms. These procedures are illustrated and explained in greater detail in subsequent sections.

RESULTS AND DISCUSSION

The distribution of scores of the science-achievement test were reasonably well spread from the lowest to the highest class intervals. Neither inspection nor statistical test, moreover, revealed any departure from normality. Ninety-five respondents, or 6.9 percent, of those in the sample, however, failed to complete all items on the test, leaving 1,284, or 93.1 percent, of the eligible sample with complete responses for analysis. Each person in the sample was given a sample weight proportional to his or her representation in the national population as a whole, reflecting NAEP's complex sampling frame and weighting procedures (see Moore, Chromy, & Rogers, 1974).

Bivariate and Partial Correlations

Table I shows the frequency distribution of items concerning three classes of variables: prior educative background and activity; current educative activity, including exposure to and reliance on mass media for information about health, science, and technology; and motivation. The educational background items concern various relatively predetermined and stable traits brought about by educative experiences that are empirically associated with test achievement as revealed by past research as well as in the category means, F-tests, correlations, and partial correlations controlled for current activities and motivation shown in the right-hand columns of the table. (The last category of each item was omitted from the correlations with achievement so that the regression equations using binary-coded variables would not be overdetermined; but the achievement trends across the items can easily be seen in patterns of the means.) Although all the educational background variables are significant, the respondent's own education and ethnicity are the strongest correlates of science achievement. The significant correlations involving ethnicity, sex, and socioeconomic status should not necessarily be interpreted as indicative of inherent characteristics but as indexes of educational and other environmental experiences that vary widely in the backgrounds of these groups. The differences, nonetheless, are large; the groups within the categories of most of the items vary by more than a full standard deviation of achievement (9.78; see Table II).

Current educative activities are also significant correlates of achievement but are somewhat smaller than prior educational background correlates. They are also reduced considerably when controlled for prior education and motivation. It is interesting to note that moderate amounts, say, about 1 or 2 hours per day of pleasure and work reading and television and radio exposure are as good as or better than lesser or greater amounts as far as science achievement is concerned. Those, however, who rely on printed material or friends for information on health, science, and technology scored considerably higher than those who rely on radio and television. The motivation scale is a moderately strong correlate of achievement controlled and uncontrolled for education and current activity, as shown in the last part of Table I. (See also Tables II and III.)

Regression Analysis

As previously mentioned, the item alternatives (save one for each item to serve as the contrast and prevent indeterminacy) were converted to binary or dummy variables. Achievement was regressed on the set or vector of educational variables and separately on the current activity variables. The two predicted achievement variables from these regressions were taken as optimally weighted composite indicators of educational background and current information acquisition activity; they extract maximum variance from the item alternatives including linear and, as noted with respect to the activity variables, nonlinear effects. Table III shows that, either in raw or logged form, they are strongly correlated with achievement, motivation, and with one another. These correlations reveal colinear, cumulative advantage: The young adults with stronger prior educational backgrounds were more strongly motivated and more intensely engaged in current activities associated with science achievement; and both these variables are correlated with achievement.

TABLE I

Frequency Response and Achievement Statistics for Item Alternative

Variable	Percent	*n*	Achievement *M*	Achievement *SD*	Achievement *F*	Correlation and partial correlation of alternatives with achievement *r*	r_p^a
			Educative background (E)				
SES (parents' education)							
Less than high school	39.3	430	27.23	9.14	83.07**	−.26**	−.17**
High school graduate	29.8	326	33.22	8.31		.14**	.10**
Post high school	19.0	208	35.92	7.93		.23**	.15**
College graduate or more	11.9	130	38.18	8.51			
Own education							
Less than high school	20.5	262	21.76	7.25	248.39**	−.47**	−.29**
Graduate from high school	29.7	381	28.36	8.37		−.16**	−.10**
Post high school	29.1	373	33.73	7.57		.19**	.10**
College graduate or more	20.7	265	39.11	7.73			
Ethnicity							
White	68.0	873	34.36	8.62	173.98**	.53**	.42**
Black	27.0	347	22.65	7.28		−.51**	−.39**
Hispanic	3.5	45	25.49	8.00		−.10**	−.08**
Others	1.5	19	28.21	8.24			
Sex							
Male	41.7	536	34.12	10.07	115.75**	−.29**	−.19**
Female	58.3	748	28.41	8.83			
Occupation							
Blue collar	22.1	277	29.10	9.72	27.67**	−.09**	−.05
White collar	29.6	370	36.23	8.33		.35**	.18**
Homemaker	23.3	291	29.26	9.19		−.09**	.03
Protective	1.7	21	33.81	9.56		.04	.05
Service	15.3	192	28.88	7.76		−.08**	−.09**
Student	1.3	16	33.56	9.29		.03	−.02
Unemployed	2.9	36	23.89	8.32		−.12**	−.08**
Other	3.8	48	28.20	10.32			
Head of household occupation							
Blue collar	38.2	299	27.54	7.99	23.94**	−.18**	−.09**
White collar	33.6	263	33.78	8.31		.15**	.08**
Homemaker	4.6	36	22.11	9.42		−.15**	−.09**
Protective	4.3	34	32.21	8.71		.02	.04
Service	7.0	55	26.13	8.53		−.10**	−.07*

TABLE I

Continued

Variable	Per-cent	n	Achievement M	Achievement SD	Achievement F	Correlation and partial correlation of alternatives with achievement r	r_p^a
Student	1.0	8	38.00	10.30		.06*	.05
Unemployed	2.8	22	19.68	6.21		−.15**	−.14**
Other	8.3	65	27.69	9.53			
Total household income							
Less than $6,000	16.7	202	24.59	8.87	75.13**	−.27**	−.20**
$6,000–11,999	27.1	327	29.28	9.16		−.09**	−.07*
$12,000–19,999	34.9	422	32.79	8.63		.14**	.11**
$20,000 or more	21.3	257	36.18	8.54			
Educational training in science or technology							
None	60.8	772	27.52	8.67	111.93**	−.41**	−.26**
Less than 2 years	25.0	318	34.62	8.61		.22**	.13**
2–4 years	7.3	93	34.89	9.81		.12**	.05
4 years or more	6.9	87	42.01	8.03			
Educational training in medicine or health sciences							
None	81.3	1,025	30.28	9.65	9.25**	−.10**	−.04
Less than 2 years	12.1	152	33.20	9.11		.09**	.02
2–4 years	4.2	53	32.55	10.69		.04	.04
4 years or more	2.5	31	37.23	9.01			
Work experience in science or technology							
No	82.6	1,033	29.42	9.19	150.03**	−.29**	−.20**
Yes	17.4	218	37.83	9.30			
Work experience in medicine or health sciences							
No	81.7	1,001	30.31	9.62	20.09**	−.09**	−.06
Yes	18.3	224	33.48	9.31			
Current activity (A)							
Reading for work per day							
None	38.4	480	28.17	9.47	24.53**	−.21**	−.01
Less than 1 hour	27.1	339	32.57	9.46		.11**	.05
1–3 hours	24.6	308	33.51	9.46		.16**	−.02
More than 3 hours	9.8	123	31.33	9.69			
Reading for pleasure per day							
None	6.7	84	23.61	10.41	18.23**	−.19**	−.08**
Less than 1 hour	45.9	574	31.48	9.37		.06**	−.02
1–2 hours	34.5	431	31.71	9.38		.07*	.04
2 hours or more	12.9	162	31.50	10.07			
Watching television per day							
None	4.1	51	31.14	13.34	27.01**	.01	.02

TABLE I
Continued

Variable	Per-cent	n	Achievement M	Achievement SD	Achievement F	Correlation and partial correlation of alternatives with achievement r	r_p^a
Less than 1 hour	20.4	255	33.04	9.81		.11**	.02
1–2 hours	32.8	409	33.32	9.05		.18**	.09**
2 hours or more	42.7	532	28.29	9.04			
Listening to the radio per day							
None	6.9	86	29.01	1.11	10.05**	−.05*	.03
Less than 1 hour	39.7	496	32.33	.44		.12**	.06*
1–2 hours	23.5	293	31.84	.57		.06*	.01
2 hours or more	29.9	373	29.08	.47			
What sources did you rely on to obtain information about health during the last 12 months?							
Broadcast media (TV, radio)							
Never	44.4	570	32.25	9.75	12.50**	.13**	.06*
Few	39.5	507	30.47	9.34		−.03	−.02
Some	13.7	176	27.90	10.18		.12**	−.04
Most	2.4	31	25.84	9.50			
Printed media (newspapers, magazines, etc.)							
Never	19.4	249	26.71	10.45	25.93**	−.21**	−.11**
Few	31.2	400	30.50	9.73		−.02	.03
Some	34.1	438	31.85	9.08		.08**	.02
Most	15.3	197	34.24	8.67			
Family or friends							
Never	74.5	957	30.73	9.71	.98	−.01	−.05
Few	23.4	301	31.00	9.85		.01	.07*
Some	1.6	21	29.52	11.62		−.02	−.06*
Most	.4	5	37.60	9.56			
Other sources							
Never	82.3	1,057	30.55	9.76	1.51	−.06*	−.02
Few	14.9	191	32.16	9.88		.06*	.02
Some	2.4	31	30.74	9.52		−.00	−.01
Most	.4	5	32.20	7.85			
Didn't get any information							
Never	70.4	904	31.08	9.74	7.29**	.05*	.04
Few	22.2	285	31.18	9.74		.02	−.02
Some	6.1	78	28.04	8.89		−.07*	−.04
Most	1.3	17	21.89	10.48			
What sources did you rely on to obtain information about science and technology during the last 12 months?							
Broadcast media							
Never	32.1	412	32.58	10.56	7.84**	.13**	.07*

TABLE I
Continued

Variable	Per-cent	n	Achievement			Correlation and partial correlation of alternatives with achievement	
			M	SD	F	r	r_p^a
Few	17.4	223	30.94	9.45		.01	.02
Some	36.4	468	29.61	9.50		−.09**	−.04
Most	14.1	181	29.64	8.36			
Variable	Percent	n	M	SD	F	r	r_p^b
Printed media							
Never	31.5	404	26.53	9.09	76.56**	−.30**	−.13**
Few	20.0	257	28.92	9.67		−.10**	−.03
Some	29.2	375	32.70	8.80		.12**	.05
Most	19.3	248	36.83	8.48			
Family or friends							
Never	95.2	1,223	30.71	9.77	.87**	−.04	−.03
Few	3.8	49	32.04	10.00		.03	.01
Some	.9	11	34.55	9.78		.04	.04
Most	.1	1	34.00				
Other sources							
Never	95.9	1,231	30.74	9.81	1.26**	−.03	−.05
Few	3.3	42	31.14	8.95		.01	.04
Some	.7	9	37.00	8.60		.53**	.02
Most	.1	2	29.00	9.90			
Didn't get any information							
Never	81.0	1,040	32.33	9.58	53.35**	.32**	.10
Few	9.7	125	25.55	7.49		−.18**	−.08**
Some	7.1	91	23.87	7.65		−.20**	−.003
Most	2.2	28	19.82	7.39			
Variable	Percent	n	M	SD	F	r	r_p^c
			Motivation (C)				
Attitude score							
Lower 25 percentile	23.5	301	23.26	8.14	178.45**	.56**	.36**
26–50 percentile	26.5	340	28.72	8.28			
51–75 percentile	26.4	338	33.17	8.50			
76–100 percentile	23.6	303	38.00	7.87			

Note. r_p^a indicates the correlation is partial out of all current activity and motivation variables; r_p^b indicates the correlation is partial out of all educational background and motivation variables; r_p^c indicates the correlation is partial out of all educational background and current activity variables.

* $p < .05$.

** $p < .01$.

A series of planned regressions containing combinations of the linear and quadratic forms of the variables as well as their products showed that two three-term equations (shown in Table III) are most parsimonious and best fitting by the criterion of adjusted accountable variances (Theil, 1971). The accountable variances of .67 and .63, respectively, for the untransformed and logged equations are highly significant. They would be increased 12.5 percent correction for attenuation for the achievement test reliability and reduced by 3 percent under the conservative assumption that 100 binary variables rather than 3 a priori composite variables entered the regressions.

The coefficients and *t*-tests show that educational background, current activity, and motivation make unique contributions to the regression when controlled for one another and when the set of variables including achievement is in either raw or logged form. The *t*-tests are greatest for educational background among the three independent variables in both equations, although all are highly significant ($p < .001$). Perhaps it should be mentioned for those familiar with the "variance-added" approach of Coleman et al. (1966) that the *T*s provide a stringent test of each variable "going in last." Equations with additional product and square terms that test for interaction and curvature among the composite variables add little and nonsignificantly to the accountable variance adjusted for the number of independent variables.

The accountable variances of the two three-term equations cannot be compared directly because they are in different metrics. To compare the

TABLE II

Univariate Statistics and Correlations

	M	*S*	*Ach*	*E*	*A*	*M*
Achievement (Ach)	30.80	9.78	—	.70	.56	.54
Educational background (E)	30.36	7.57	.77	—	.54	.32
Current activity (A)	30.78	5.59	.57	.55	—	.34
Motivation (M)	42.44	8.23	.56	.45	.38	—

Note. The correlations for logged variables are above the diagonal. Correlation of .05 and .08 are respectively significant at the.05 and .01 levels.

TABLE III

Regression of Untransformed and Logged Variables

	Constant	Education	Activity	Motivation	R^2	Error
Untransformed	−13.03	.73	.30	.29	.67	5.65
(*T*)		(27.5)	(8.8)	(13.4)		
Logged	−1.80	.71	.38	.39	.63	5.63
(*T*)		(24.7)	(9.2)	(17.1)		

Note. Both R^2 and all *T*s are significant beyond the .01 level. The ratio of the variances of the errors from the two equations is 1.006 and not significant.

overall equations, the predicted values from the logged equation were transformed back into the original raw metric and subtracted from the observed values; the errors or standard deviations of these residuals are shown in the last column of Table III. The logged equation produced a slightly smaller error of prediction; but the ratio of the variances, 1.006, is not significant at the conventional .05 level. Thus, the Cobb-Douglas logged form provides a slightly better but not significantly better fit than the additive, linear model. Figure 1 shows that the curvature of the logged fit is slight and that, reflecting its importance and larger weights in the regression, the slope for prior education is higher than current educational activity.

The issues that these data do not resolve are theoretically and practically important. The linear equation implies that adding more of any one of the three factors would keep increasing achievement indefinitely and independently of the other factors; more and more motivation, for example, would increase achievement indefinitely even if current activity remained the same. The logged form implies that each factor has diminishing returns when the others are fixed because all three factor coefficients are less than one; increasing motivation beyond a point, for example, would be less productive than also increasing current activity. It further implies, however, increasing returns to scale because the factor coefficients sum to greater than one, and doubling them all, perhaps by increasing the scale of both motivation and lifelong education or perhaps by personal specialization, would more than double achievement. Because the efficient allocation of scarce resources to competing goals requires knowledge of the production function, it would be useful to know the true form of the equation. The limitations of educational measures are likely to continue to make the resolution of the issues difficult.

CONCLUSIONS

Within the constraints of the cross-sectional data, it appears that general science achievement among young adults depends on relevant prior educational background, current educative activity, and motivation; and that educational background, including psychological aspects of environments experienced in schools, ethnic and socioeconomic groups, and families weighs most heavily. The three factors, even though each makes a significant contribution to the accountable variance, are colinear; those advantaged on one are likely to be advantaged on the other two. The advantages are not only colinear but cumulative, because prior educational background predicts current educative activity and motivation and all three contribute to achievement. Thus, two aspects of the Matthew effect are supported.

The data, however, show no clear-cut superiority of the Cobb-Douglas multiplicative, diminishing-returns model over an additive, linear model. Thus, whether achievement is determined by processes of multiplicative efficiency or additive compensation remains for subsequent research to

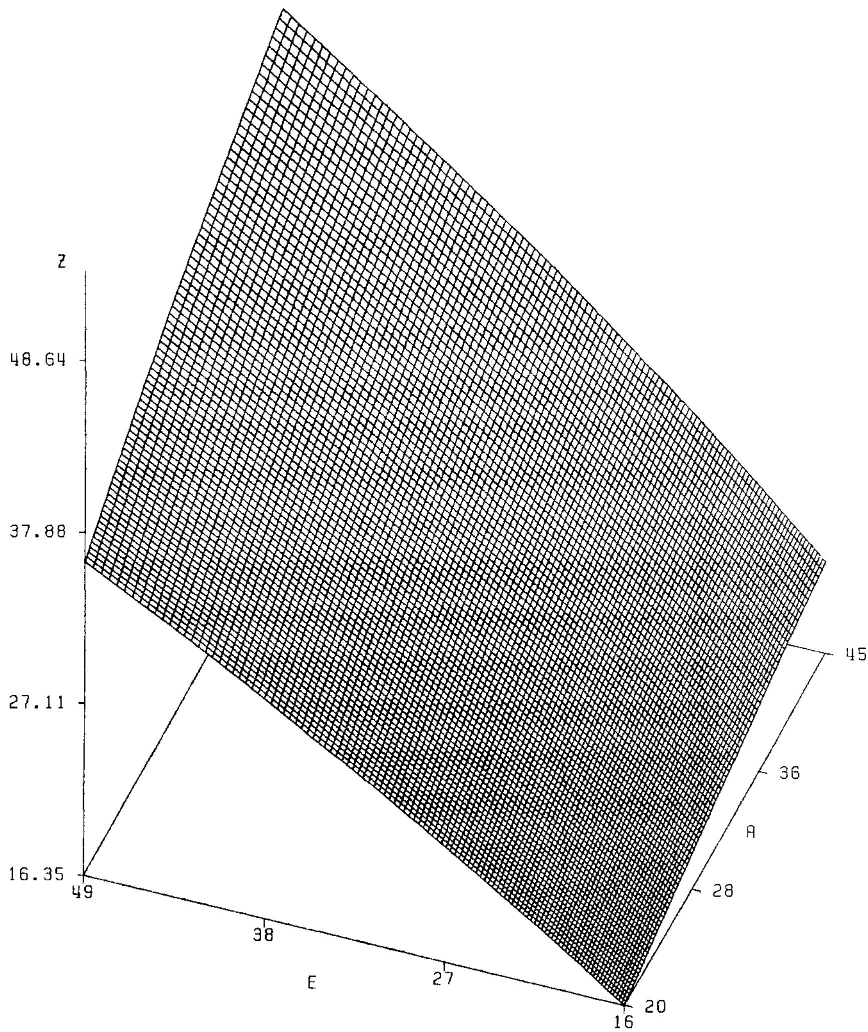

FIGURE 1. Knowledge (Z) as a Function of Educative Background (E) and Activity (A).

answer. Furthermore, the possibility of reverse causation, for example, motivation and activity enhanced by achievement, should also be acknowledged and investigated. Longitudinal achievement data with daily logs of activities of a large, diversified sample would be difficult and expensive to obtain but would permit a better assessment of these latter questions.

REFERENCES

BOSWORTH, D. L. *Production functions.* Lexington, Mass.: D. C. Heath, 1976.

COBB, C. W., & DOUGLAS, P. H. A theory of production. *American Economic Review* 1928, *18* (Supplement), 139–165.

COLEMAN, J. S., CAMPBELL, E. Q., HOBSON, C. J., MCPARTLAND, J., WEINFELD, F. D., & YORK, R. L. *Equality of educational opportunity.* Washington, D. C.: U. S. Government Printing Office, 1966.

COOK, T. D., & CAMPBELL, D. T. *Quasi-experimentation.* Chicago: Rand-McNally, 1979.

COOK, T. D., APPLETON, H., CONNOR, R., & SCHAFFER, A. *Sesame Street revisited: A case study in evaluation research.* New York: Russell Sage, 1975.

FREDERICK, W., & WALBERG, H. J. Learning as a function of time. *Journal of Educational Research,* 1980, *73,* 183–194.

HILL, R. C., & STAFFORD, F. P. The allocation of time to preschool children and educational opportunity. *Journal of Human Resources,* 1974, *9,* 323–341.

JONES, H. G. *An introduction to modern theories of economic growth.* New York: McGraw-Hill, 1976.

MERTON, R. K. The Matthew effect in science. *Science,* 1968, *175,* 56–63.

MOORE, R. P., CHROMY, J. R., & ROGERS, W. T. *The national assessment approach to sampling.* Denver, Colo.: NAEP, 1974.

NELSON, R. R. Research on productivity growth and productivity differences. *Journal of Economic Literature,* 1981, *19,* 1029–1064.

POPPER, K. R. *Objective knowledge: An evolutionary approach.* Oxford, England: Clarendon, 1972.

ROBERTS, D. F., & BACHEN, C. M. Mass communication effects. *Annual Review of Psychology,* 1982, *33,* 477–514.

SCHULTZ, T. W. *Investing in people.* Berkeley: University of California Press, 1981.

SIMON, H. A. Information processing models of cognition. *Annual Review of Psychology,* 1979, *30,* 363–396.

THEIL, H. *Principles of econometrics.* New York: John Wiley & Sons, 1971.

WALBERG, H. J. A psychological theory of educational productivity. In F. H. Farley & N. Gordon (Eds.), *Psychology and education.* Berkeley, Calif.: McCutchan, 1981.

WILLSON, V. L. *A meta-analysis of the relationship between science achievement and science attitude: Kindergarten through college.* Washington, D. C.: National Association for Research in Science Teaching, 1981.

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